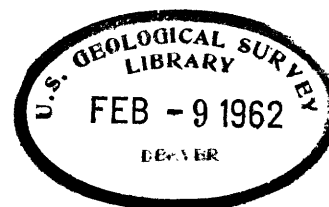


GEOLOGY AND MINERALOGY

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

URANIFEROUS COAL AND CARBONACEOUS SHALE
IN NORTHEAST PARANÁ, BRAZIL*



By

Donald D. Haynes and Charles T. Pierson

*This report concerns work performed by the Brazilian National Nuclear Energy Commission and the United States Geological Survey (on behalf of the United States Atomic Energy Commission), and it is published with the permission of these agencies.

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URANIFEROUS COAL AND CARBONACEOUS SHALE
IN NORTHEAST PARANA, BRAZIL

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URANIFEROUS COAL AND CARBONACEOUS SHALE IN NORTHEAST PARANÁ, BRAZIL

ABSTRACT

Uraniferous coal has been found in northeast Paraná, Brazil, in the Rio Bonito formation of Pennsylvanian age. In the majority of coal samples taken the uranium oxide content ranges from 0.005 to 0.030 percent, but selected screened samples have contained as much as 0.445 percent uranium oxide. The sampled thickness of the coal seam ranges from 17 to 54 centimeters and averages 31 centimeters. Channel samples across the entire thickness of the coal zone were taken in two places. All other samples were taken as grab samples from either mine waste dumps or coal zones that had high radioactivity.

Sufficient information is not yet available to justify any detailed considerations of such features as geologic distribution, mode of occurrence, and radioactive equilibrium conditions of the uranium in the coal.

INTRODUCTION

Early in April 1956, during a check for radioactive rocks of part of the collection of sedimentary rocks of the Departamento Nacional da Produção Mineral, Rio de Janeiro, pieces of radioactive coal were found. Chemical analysis of the most radioactive piece of coal, from the village of Nova Toquio (formerly Artur Bernardes) in northeast Paraná (see pl. 2) indicated the presence of 0.03 percent uranium oxide.

Immediately thereafter the State Geological Survey and the Instituto do Biologia e Pesquisas Tecnológicas of the State of Paraná made arrangements to begin a program for the reconnaissance of uraniferous coal. Complete cooperation was offered by all agencies consulted. The government of the state placed several vehicles at the disposition of the geologists and also assigned to them the use of a four-place airplane and a two-place helicopter.

The field work was done during May and July 1956 by geologists of the official Brazil-United States joint group evaluating the uranium resources of Brazil. Initial work in the Cambuí area was done by C. T. Pierson and Helmuth Wedow, Jr., of the U. S. Geological Survey and Luiz Zingoni of the Brazilian group. Later, airborne work was done by D. D. Haynes and Luiz Zingoni in the Campina dos Pupos-Harmonia area, the Ibaiti-Nova Toquio-Carvãozinho area, the Wenceslau Braz-Barbosas area and the Figueira area.

This report concerns work performed by the Brazilian National Nuclear Energy Commission and the United States Geological Survey (on behalf of the United States Atomic Energy Commission), and it is published with the permission of these agencies.

Individuals contributing to the work reported herein are Dr. M. A. Enrietti, Dr. R. Maack, Dr. Alsedo Leprevost and Arnaldo Sobanski of the Instituto de Biología e Pesquisas Tecnológicas of Curitiba, Paraná, and Manuel de Oms of the Ministerio da Agricultura, State of Paraná.

The purpose of this report is to present all available data on the radioactivity and uranium content of the coal; discussion of the data is held to a minimum. This is because, as yet, insufficient information is available to justify any detailed consideration of such features as geologic distribution, mode of occurrence, and radioactive equilibrium conditions of the uranium in the coal. These and other features of the coal will be considered when sufficient data result from field work, which is continuing, and from laboratory studies.

GEOLOGY OF THE COAL-BEARING FORMATIONS OF PARANÁ

In the State of Paraná the coal beds occur in the Rio Bonito formation, a part of the Tubarão series of Pennsylvanian age (fig. 1). The rocks are a part of the Gondwanian sedimentary sequence that constitute White's "Santa Catarina System" (1908). The Tubarão series is exposed in an arcuate belt in the east-central part of Paraná (pl. 1). The belt, which has a general north-south trend, extends from the southern border to the northeast border of the state, and is about 330 kilometers long and 30 to 70 kilometers wide.

The Tubarão series lies unconformably on Lower Devonian and pre-Devonian sedimentary and metamorphic rocks. It is divided into two groups; the lower, the Itararé group, is composed of sedimentary rocks of glacial origin, and the upper, the Guatá group, is a post-glacial sequence which contains the coal zones. As in other states of south Brazil, it is difficult to differentiate between the two groups.

Itararé group

In Paraná the Itararé group has been divided (Maack, 1947) into two formations: the lower, the Palmira, of continental-glacial origin; and the upper, the Taió, of glacial-marine origin. The Palmira formation is composed of tillites, fluvial-glacial sandstones, varvites, and eolian deposits. Its thickness ranges from 320 to 370 meters. The Taió formation is made up of conglomerates interbedded with clay and shale beds. This formation is highly fossiliferous and up to four fossil zones have been found. Its thickness ranges from 65 to 100 meters.

Period	Series	Group	Formation	Characteristics	Range of Thickness (in meters)	Average Thickness (in meters)
Permian Inferior	Passa Dois	Irati		Bituminous black shale		
Carbonifero Superior (Pennsylvanian)	Tubarão	Guatá	Palermo ("beds")	Sandstone Shale	50-90	
		(Upper Pennsylvanian)	Rio Bonito	Sandstone Siltstone Shales Clay beds Coal	80-150	610
		Itararé	Taio	Conglomerates interbedded with clay and shale beds	65-100	
			Palmira	Tillites, fluvial-glacial sandstones, varvites and eolian deposits	320-370	
			Unconformity			

Figure 1. Stratigraphic sequence of the Tubarão and Passa Dois series in Paraná, Brazil.

Guatá group

The Guatá group (Gordon, 1947) is divided into two sedimentary formations: the Rio Bonito, containing the coal zones; and the Palermo, composed predominantly of continental sedimentary rocks without coal.

The Rio Bonito formation is the older of the two, and in the southern part of the state it consists of sandstone and claystone beds that are rich in fossils. In the central and northern parts of the state it consists of sandstones, siltstones and shales that reach a thickness of 150 meters, and usually contains one, but in some places, two coal zones.

The Palermo formation, which is usually referred to as the "Palermo beds" or "Palermo shale," overlies the Rio Bonito formation conformably. These beds contain no glacial deposits and no coal. The beds consist of gray and yellowish sandy shale interbedded with white, reddish and yellow sandstone, and bands and nodules of chert. In the Palermo strata are found plants and fossil shells of fresh-water origin and fragments of silicified wood of the genus *Dadoxylon*. The Palermo underlies the Iratí bituminous black shale of the Passa Dois series of Permian age and ranges in thickness from 50 to 90 meters.

COAL REGIONS

There are two coal-bearing regions in Paraná, one in the northeast and one in the southeast part of the state (G. M. de A. Oliveira, 1953). There are two coalfields in the northeast region, the Rio das Cinzas and the Rio do Peixe; and in the southeast region there is one, the Rio Tibagi (pl. 2).

Of the coalfields in Paraná only the Rio do Peixe in the vicinity of the towns of Cambuí, Figueira and Ibaíti has coal of sufficient quality and quantity to warrant large-scale mining operations. With the exception of the coal basin in the Cambuí district in the Rio do Peixe coalfield, the coal basins are, by and large, of small dimensions. The coal basin in the Cambuí district covers an area approximately 8 by 9 kilometers.

The minable coal is obtained from the Rio Bonito formation, and in all the coal regions of the state the coal is extracted from a single coal zone that is usually divided into two coal seams separated by a thin bed or split of sandstone or carbonaceous shale which averages about 60 centimeters in thickness. The thickness of the coal zone ranges from 30 to 130 centimeters and averages about 75 centimeters. In the Cambuí district Pierson has found that the thickness of the coal ranges from 50 to 150 centimeters and of the carbonaceous shale or sandstone splits from 20 to 50 centimeters.

The coal in Paraná is mostly bituminous but ranges from subbituminous to semi-anthracite. Ash content ranges from 15 to 40 percent, and sulfur content is as high as 12 percent. Large nodules of pyrite are very common.

Coalfields of Paraná

<u>Region</u>	<u>Coalfield</u>	<u>District</u>
Northeast	Rio das Cinzas	(Barbosas (Tomazina (Ibaití
	Rio do Peixe	(Carvãozinho (Euz. de Oliveira (Cambuí (Pelame
Southeast	Rio Tibagi	(Salto Aparado
		(Campina dos Pupos
		(José Lacerda
		(Cedro) Not shown
		(Imbituva) on
		(Teixeira Soares) plate 2

RADIOACTIVITY INVESTIGATIONS

Field investigation for uraniferous coal was on a reconnaissance scale in the Rio das Cinzas, Rio do Peixe and Rio Tibagi coalfields (pl. 2). Field checking for radioactivity was done on the ground using a scintillation or Geiger-Müller counter, and by air using an airborne scintillation counter mounted in either a four-place airplane or two-place helicopter.

Samples collected from areas showing appreciable radioactivity were taken for radiometric and chemical analysis to the project laboratory in the Laboratorio da Produção Mineral in Rio de Janeiro. Several samples were also sent for chemical analysis to the U. S. Geological Survey's laboratory in Washington, D. C. In this report the samples are arranged into "sample groups," each group representing the sampling to date in a selected area. An individual "sample group" is not related to a coal district or coal basin but is given the name of a city which lies in the area of the sample group. The "sample groups" are used both in the text and on the maps.

Samples PnC-3A through 3F and 4A through 4G are samples taken from two channels cut across the entire thickness of the coal zone. When no thickness is given, it can be assumed the sample is a grab sample and was taken from a mine dump or a coal zone which was highly radioactive.

Cambuí-Figueira area

The Rio do Peixe coalfield has been the principal coal-producing area in northeast Paraná and, therefore, was investigated first because of the larger number of mines and outcrops that are accessible for examination.

More than 15 mines were examined radiometrically, and samples (group A, pl. 2) were collected from six localities for chemical analysis. Drill cores from several holes were also examined, but none seemed to be abnormally radioactive.

The radiometric data obtained from the field investigations are plotted on plate 3. The maximum radioactivity at each locality examined is indicated by a number, which expresses radioactivity in terms of number of times above background (0.006 mr/hr). Two areas of significant anomalous radioactivity are apparent, one north of Estação Lisimaco Costa (Cambuí) and one east of Figueira.

A 20-centimeter channel sample was taken from the upper part of a 93-centimeter coal zone at the Lupion Campo 2 mine. The original sample was cut through a hard, blocky coal 11 centimeters thick (the upper coal seam) and a fissile coal, 9 centimeters thick and containing abundant thin partings of carbonaceous shale. The sample was screened and divided into four parts (PnC-34A, 34B, 34C, and 34D) in order to determine whether the uranium was concentrated in the fissile coal, carbonaceous shale or the hard, blocky coal. Results of the chemical analysis on the separated fractions are as follows:

- PnC-34A - 0.183 percent U_3O_8 , + 4 mesh fraction consisting mainly of the hard, blocky type of coal.
- PnC-34B - 0.33 percent U_3O_8 , -4 +10 mesh fraction consisting of some hard, blocky type of coal, but mainly of the fissile type and shaly coal.
- PnC-34C - 0.415 percent U_3O_8 , -10 +20 mesh fraction consisting mainly of shaly coal and carbonaceous shale.
- PnC-34D - 0.445 percent U_3O_8 , -20 mesh fraction consisting of carbonaceous shale and fine particles of fissile coal.

No conclusions can be made at this time from so few samples or from so little field work, but the highest grade of uranium seems to be in the carbonaceous shale. In the above samples the uranium is not in equilibrium with its daughter products; the uranium content determined chemically is higher than the content determined radiometrically.

The results of analyses of samples collected from the Cambuí-Figueira are given in table 1.

Table 1. Analysis of samples collected from the Cambuí-Figueira area.

<u>Field no.</u>	<u>Percent eU₃O₈ in sample</u>	<u>Percent U₃O₈ in sample</u>	<u>Percent U₃O₈ in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-1	0.028	0.031	0.443	7.0	Coal from upper part of coal zone.
PnC-3A	0.011	0.008	0.009	97.4	30 cm. limonite-stained sandstone above coal zone.
PnC-3B	0.047	0.053	0.18	30.2	21 cm. fissile coal from upper coal seam.
PnC-3C	0.061	0.068	0.68	9.9	17 cm. blocky and fissile coal from upper coal seam.
PnC-3D	0.021	0.010	0.012	80.8	50 cm. carbonaceous shale and coal from shale split.
PnC-3E	0.024	0.017	0.057	30.1	50 cm. blocky coal from lower coal seam.
PnC-3F	0.004	0.001	0.001	95.9	25 cm. underclay below coal seam.
PnC-4A	0.004	0.001	0.001	95.7	25 cm. underclay below coal seam.
PnC-4B	0.004	0.003	0.012	25.6	54 cm. blocky coal from lower coal seam.
PnC-4C	0.018	0.012	0.015	79.4	20 cm. carbonaceous shale from shale split.
PnC-4D	0.022	0.026	0.073	35.0	19 cm. blocky, shaly coal from upper coal seam.
PnC-4E	0.026	0.021	0.022	94.7	31 cm. siltstone above coal zone.
PnC-4F	0.025	0.024	0.025	94.4	36 cm. gray siltstone above coal zone.
PnC-4G	0.024	0.017	0.018	96.0	46 cm. sandstone and siltstone above coal zone.

Table 1. Analysis of samples collected from Cambui-Figueira area (continued).

<u>Field no.</u>	<u>Percent ^{238}U in sample</u>	<u>Percent U_3O_8 in sample</u>	<u>Percent U_3O_8 in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-5	0.020	0.018	0.019	92.9	Carbonaceous sandstone above coal zone.
PnC-34A	0.103	0.183	0.704	26.0	20 cm. coal +4 mesh fraction.
PnC-34B	0.203	0.330	1.126	29.3	20 cm. coal -4 +10 mesh fraction.
PnC-34C	0.235	0.415	1.182	35.1	20 cm. shaly coal and carbonaceous shale -10 +20 mesh fraction.
PnC-34D	0.256	0.445	1.132	39.3	20 cm. fine coal and carbonaceous shale -20 mesh fraction.
PnC-37	0.009	0.003	0.003	91.0	Grab sample of sandstone from waste dump.
PnC-40	0.034	0.017	0.018	92.1	35 cm. sandstone from above coal zone.
PnC-42	0.008	0.021	0.096	21.9	Grab sample of coal from coal zone.

Campina dos Pupos area

Coal samples (group B, pl. 2) were collected from a mine and a coal outcrop south of Campina dos Pupos. The coal was only slightly radioactive; the highest grade sample contained 0.011 percent U_3O_8 .

Table 2. Analysis of samples collected from the Campina dos Pupos area.

<u>Field no.</u>	<u>Percent eU₃O₈ in sample</u>	<u>Percent U₃O₈ in sample</u>	<u>Percent U₃O₈ in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-6	-	-	-	-	Coal, not radioactive, grab sample.
PnC-7	0.009	0.003	0.006	50.0	Coal, grab sample.
PnC-8	0.013	0.011	0.042	26.5	Coal, grab sample.

Harmonia

Two samples (group C, pl. 2) were collected from the ash dump of the paper factory at Harmonia. The coal consumed at the factory is from the I.K.P.C. mine near Bairro dos Antas, and is usually burned with wood.

Table 3. Analysis of samples collected from the factory at Harmonia.

<u>Field no.</u>	<u>Percent eU₃O₈ in sample</u>	<u>Percent U₃O₈ in sample</u>	<u>Percent U₃O₈ in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-9	0.023	0.007	0.009	74.0	Cinders from paper factory.
PnC-10	0.009	0.002	0.002	83.6	Cinders from paper factory.

Bairro dos Antas area

Six samples (group D, pl. 2) were collected from the I.K.P.C. mine northwest of Bairro dos Antas (in the Salto Aparado district). All the samples except one were from the coal zone or the overlying shale in Gallery 3 (name of drift in mine). One sample, PnC-16, was taken from the material filling a fault that offset the coal zone in Gallery 4 (name of drift in mine).

Table 4. Analysis of samples collected from the Bairro dos Antas area.

<u>Field no.</u>	<u>Percent eU_3O_8 in sample</u>	<u>Percent U_3O_8 in sample</u>	<u>Percent U_3O_8 in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-11	0.008	0.002	0.007	29.1	Coal from upper part of zone, grab sample.
PnC-12	0.011	0.006	0.007	89.7	Shale from lower part of zone, grab sample.
PnC-13	0.022	0.009	0.010	88.4	Shale overlying coal zone, grab sample.
PnC-14	0.009	0.005	0.006	88.6	Shale overlying coal zone, grab sample.
PnC-15	0.008	0.005	0.045	11.0	Coal, grab sample.
PnC-16	0.026	0.005	0.006	87.6	Material from fault zone, grab sample.

Ibaiti' area

The mine at Ibaiti', in the Ibaiti' district of the Rio das Cinzas coal-field, was checked for radioactivity, and three samples (group E, pl. 2) were collected from an outcrop near the portal. One sample contained 0.04 percent U_3O_8 . Airborne work with a scintillation counter indicated a large abnormally radioactive area surrounding the mine, but further sampling was not undertaken because of lack of outcrops.

Table 5. Analysis of samples collected from the Ibaiti' area.

<u>Field no.</u>	<u>Percent eU_3O_8 in sample</u>	<u>Percent U_3O_8 in sample</u>	<u>Percent U_3O_8 in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-26	0.011	0.008	0.009	91.1	Sandy shale above coal zone.
PnC-27	0.041	0.040	0.117	34.2	40 cm. coal from upper part of zone.
PnC-28	0.023	0.018	0.026	70.0	10 cm. carbonaceous shale from shale split.

Nova Toquio area

Two samples (group F, pl. 2) were collected from Nova Toquio (formerly Artur Bernardes), one from the coal zone and one from the waste dump. Neither sample contained a significant amount of uranium, and airborne work indicated only very weak radioactivity in the area of the mines.

Table 6. Analysis of samples collected from the Nova Toquio area.

<u>Field no.</u>	<u>Percent eU₃O₈ in sample</u>	<u>Percent U₃O₈ in sample</u>	<u>Percent U₃O₈ in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-29	0.006	0.001	0.004	24.4	Shale and coal from waste dump, grab sample.
PnC-38	0.009	0.005	0.038	13.1	Coal from upper part of zone, grab sample.

Barbosas area

At Barbosas five samples (group G, pl. 2) were collected. Only one sample contained more than 0.003 percent U₃O₈. Airborne work in the area failed to disclose any significant anomalies.

Table 7. Analysis of samples collected from the Barbosas area.

<u>Field no.</u>	<u>Percent eU₃O₈ in sample</u>	<u>Percent U₃O₈ in sample</u>	<u>Percent U₃O₈ in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-31	0.006	0.003	0.003	98.8	Sandstone above coal zone, grab sample.
PnC-32	0.011	0.007	0.014	49.7	Shale above coal zone, grab sample.
PnC-33	0.009	0.002	0.005	42.0	Coal, grab sample.
PnC-39	0.009	0.002	0.005	39.4	Grab sample of coal from waste dump.
PnC-44	0.003	0.002	0.005	43.5	Coal, grab sample.

Carvãozinho area

Three samples (group H, pl. 2) were collected from Carvãozinho, which is located on the east side of the Rio do Peixe coalfield. The highest grade sample contained only 0.01 percent U_3O_8 , but an airborne scintillation survey indicated several radiometric anomalies that were much stronger than those samples. It was not possible to sample the stronger anomalies because of their inaccessibility. A grab sample of alluvial sand (PnC-43) was taken from a stream running from the portal of a mine.

Table 8. Analysis of samples collected from the Carvãozinho area.

<u>Field no.</u>	<u>Percent eU_3O_8 in sample</u>	<u>Percent U_3O_8 in sample</u>	<u>Percent U_3O_8 in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-35	0.018	0.006	0.007	84.3	33 cm. channel sample of coal from top of zone.
PnC-41	0.015	0.010	0.028	35.4	Coal from top of zone, grab sample.
PnC-43	0.005	0.002	0.002	98.4	Alluvial sand from stream running from mine.

Wenceslau Braz area

Sample PnC-30 (group J, pl. 2) was collected from the sandstone immediately overlying the coal zone. The sandstone, containing 0.007 percent eU_3O_8 , but less than 0.001 percent U_3O_8 , appeared to be more radioactive than the coal; therefore, no samples were collected from the coal.

Table 9. Analysis of sample collected from the Wenceslau Braz area.

<u>Field no.</u>	<u>Percent eU_3O_8 in sample</u>	<u>Percent U_3O_8 in sample</u>	<u>Percent U_3O_8 in ash</u>	<u>Per-cent ash</u>	<u>Description</u>
PnC-30	0.007	>0.001	-	97.4	Sandstone overlying coal zone.

RECOMMENDATIONS

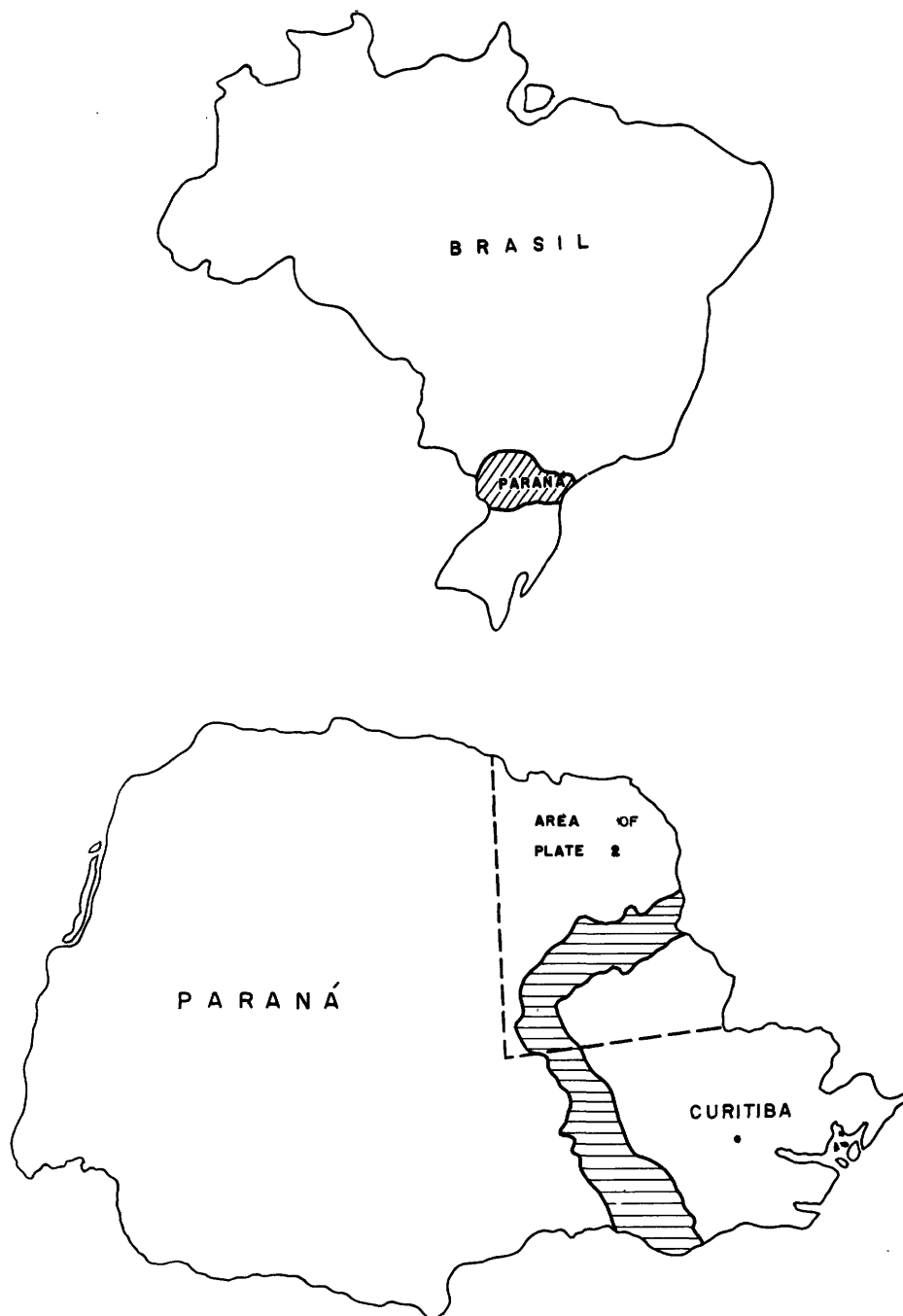
Preliminary reconnaissance in northeast Paraná has revealed the presence of uranium-bearing coal in several areas. The more important areas in which detailed study should be undertaken are:

1. The areas north of Estação Lisimaco Costa (Cambuí) and east of Figueira.
2. The area around the mines at Carvãozinho.
3. The area around the mine at Ibaíti.

If uranium-bearing coal of economic quantity and quality is found in the above areas, further work might be advisable in some of the other areas in which uranium-bearing coal of lower grade was found.

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MAP AFTER E. OLIVEIRA
AND R. MAACK

0 20 40 60 80 100 Km
ESCALA

EXPLANATION



-  Tubarão Series
(Pennsylvanian)
-  Boundary enclosing area
covered by Plate 2.
Limites da área da Prancha 2

PLATE 1. SKETCH MAP OF PARANÁ SHOWING DISTRIBUTION OF TUBARÃO SERIES
PRANCHA 1. MAPA ESQUEMÁTICO DO PARANÁ, MOSTRANDO A DISTRIBUIÇÃO DA SÉRIE TUBARÃO

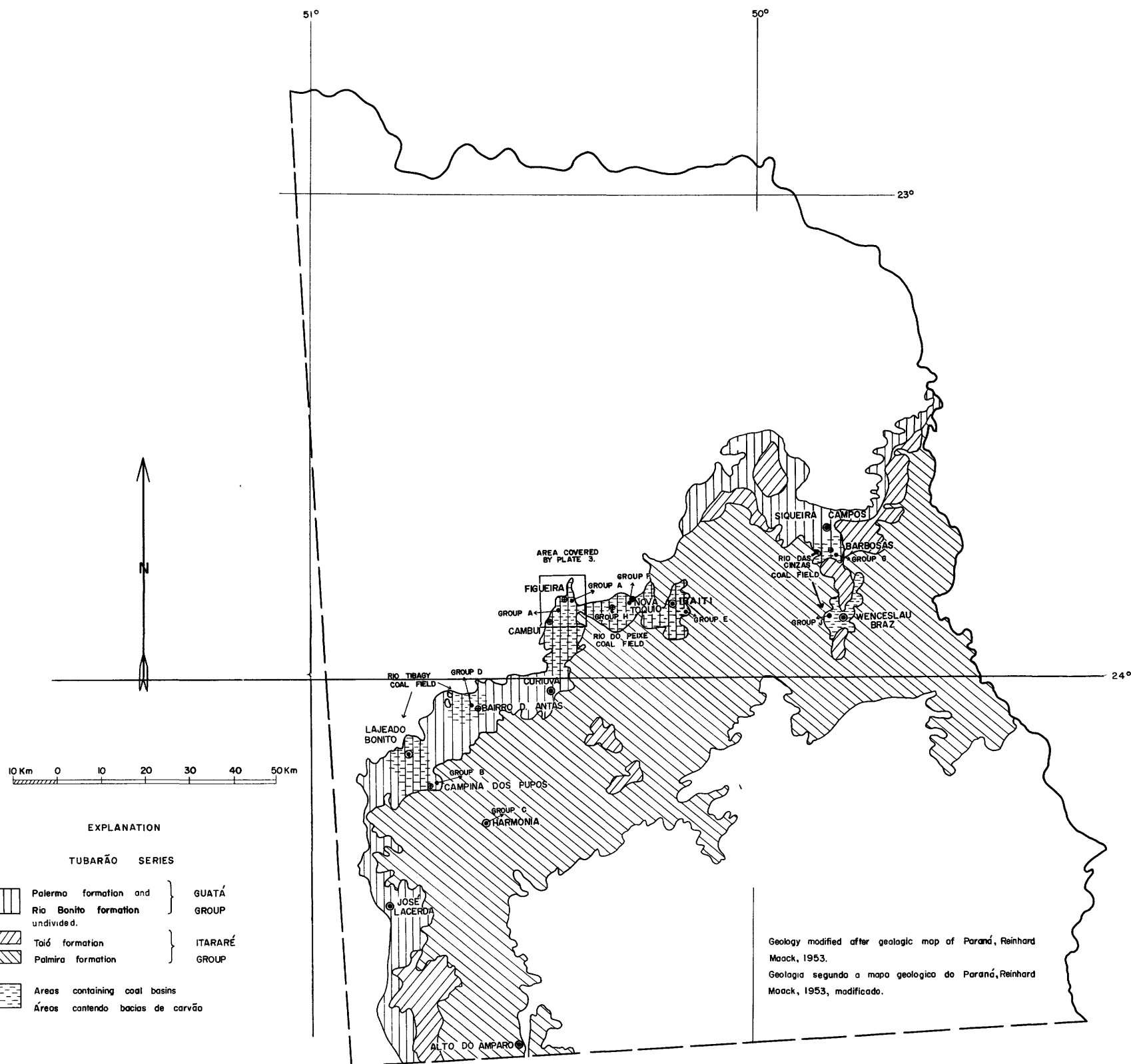


PLATE 2 — Sketch map of northeast Paraná showing distribution of Tubarão series, location of sample points and area covered by plate 3.

PRANCHA 2— Mapa esquemático do nordeste da Paraná, mostrando a distribuição da série tubarão, a locação dos pontos amostrados e a área incluída na prancha 3.

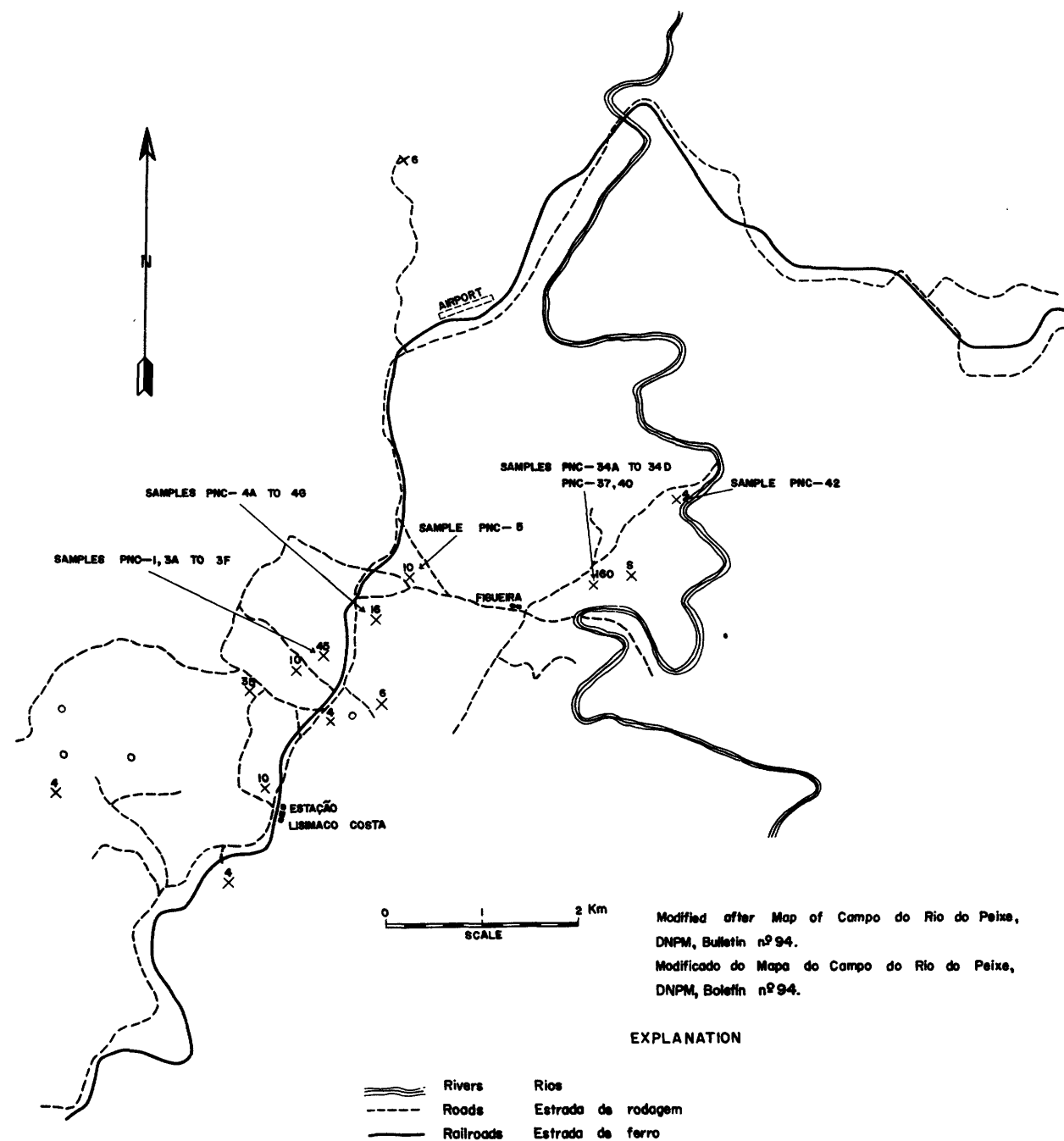


PLATE 3 — Sketch map of Rio do Peixe coal field showing locations of mines and outcrops checked for radioactivity.
PRANCHA 3 — Mapa esquemático da área de Rio do Peixe mostrando a localização das minas e afloramentos verificados para radioatividade.